Modeling and Forecasting A Groundwater Dominated Ecosystem

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Some Papers


Questions

How does precipitation impact stream baseflow in a native prairie ecosystem?

How do plants interact with groundwater?

How does the sloping base of the Ogallala Aquifer control groundwater flow?

How do natural and anthropogenic processes interact?
Modeling Framework

Processes and Properties

Framework

Problems
- Groundwater/Surface Water
- Phreatophytes
- Sloping Base
- Society

Conclusions

Yang, Steward, de Lange, Chubb, Bernard (2010)

Data
- Pumping wells
- Water level Obs.
- Soils
- Surface elevation
- Boreholes
- Rainfall
- Geology

Conceptualization
- Number of aquifer layers?
- Confined/unconfined?
- Heterogeneities?
- Aquifer properties?
- Boundary conditions?

Modeling
- Finite difference method
- Finite element method
- Analytical element method

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**Framework**

**Problems**

**Groundwater/Surface Water**

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**Conclusions**

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(a) Perennial streams in the lowland prairie, with the Kansas River valley in the far distance to the left.

(b) Ephemeral streams in the upland prairie.

(c) Conceptual model and variables.

Steward, Yang, Lauwo, Staggenborg, Macpherson, Welch (2011)
Soils of the northern Flint Hills

Framework

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Conclusions
Surface water fluxes
Partitioning precipitation

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Fig. 4. Mean estimates for evapotranspiration, runoff, and recharge plus and minus one standard deviation for the soils of the study region.

Steward, Yang, Lauwo, Staggenborg, Macpherson, Welch (2011)
Groundwater recharge

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Fig. 5. Spatial distribution of recharge in the study region and at Konza LTER.

Steward, Yang, Lauwo, Staggenborg, Macpherson, Welch (2011)
Groundwater models

Different model; same results

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Fig. 8. Depth to water in the study region and at Konza LTER

Steward, Yang, Lauwo, Staggenborg, Macpherson, Welch (2011)
Cottonwoods near diversion

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Cheyenne Bottoms
Salt cedars in river corridors

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Yang and Steward (2012)
a. Groundwater and a phreatophyte

b. Groundwater root uptake functions

*Figure 1.* Variables used to delineate groundwater flow associated with a phreatophyte, and three functional approximations for the specific discharge of groundwater uptake by a phreatophyte presented in dimensionless form.

Steward and Ahring (2009)
Isolated plant

Head and fluxes beneath a tree

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Local model of a tree

Capture zone of a phreatophyte

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Steward and Ahring (2009)
Plant to regional scales

Fields of phreatophytes

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1. Aerial photograph

Steward and Ahring (2009)
A regional model of phreatophytes and fields

Capture zones

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Steward and Ahring (2009)
Gently sloping aquifer

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Groundwater Depletion

Estimated Usable Lifetime

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Source: USGS (water.usgs.gov)
Source: KGS (www.kgs.ukans.edu)
Figure 1. Groundwater parameters for a sloping base: (a) sloping base; (b) stepping base approximation.

Steward (2007)
Predevelopment groundwater elevation [m above m.s.l.] and predevelopment saturated thickness [m] in three regions.

Wells and observed changes in saturated thickness ∆H [m] from predevelopment to 2005

Steward, Yang, Chacon (2009)
Ogallala Aquifer

Water Use

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12 April 2012

Steward, Yang, Chacon (2009)
Ogallala Aquifer

Groundwater Declines: Existing and Projected

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Modeled and observed change in saturated thickness over the time of historical water-use records (1988–2005)

a. Sheridan County, KS

b. Scott County, KS

c. Seward County, KS

Forecasted change in saturated thickness occurring 20 years after historical water-use records (2025)

d. Sheridan County, KS

e. Scott County, KS

f. Seward County, KS

Forecasted change in saturated thickness occurring 50 years after historical water-use records (2055)

g. Sheridan County, KS

h. Scott County, KS

i. Seward County, KS

Steward, Yang, Chacon (2009)
Irrigated agriculture

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Important Data

Groundwater, Crop, Climate

Framework

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Steward, Peterson, Yang, Bulatewicz, Herrera, Mao, Henderson (2009)
Well-parcel relationship

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Steward, Petersin, Yang, Bulatewicz, Herrera, Mao, Henderson (2009)
Economics

Linked models

Water availability

Agri-Economic Model

Land-use

Economic Parameters

- Market prices
- Policy (incentives/regulations)
- Parcel properties

Steward, Peterson, Yang, Bulatewicz, Herrera, Mao, Henderson (2009)

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Crop choice

Agro-Ecologic Model

Agriculture Parameters
- Crops
- Management choices
- Soils
- Weather

Linked models

Agriculture

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Bulatewicz, Jin, Staggenborg, Lauwo, Miller, Das, Andresen, Peterson, Steward and Welch (2009)
Linked models

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Water-use

Groundwater Model

Water stores

Hydrogeologic Parameters
- Aquifer properties
- Water properties

Yang, Steward, de Lange, Lauwo, Chubb, Bernard (2010)
OpenMI linkages

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2012 Water Seminar: Steward KSU
Integrated model forecasts

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Bulatewicz, Yang, Peterson, Staggenborg, Steward, Welch (2010)
Integrated model forecasts

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**b) Regulation policy**

- Total Water Use (x10^3 m^3)
- Water Level Change (m)
  - High: 1.0
  - Low: -0.3

- Total Revenue ($ x 10^3)

- Most Frequent Crop Choice

**c) Incentive policy**

- Total Water Use (x10^3 m^3)
- Water Level Change (m)
  - High: 1.0
  - Low: -0.3

- Total Revenue ($ x 10^3)

- Most Frequent Crop Choice

Bulatewicz, Yang, Peterson, Staggenborg, Steward, Welch (2010)
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Range of groundwater problems

Data → Conceptualization → Model

Knowledge to support informed decision making